# Detection and location of high voltage cable sheath damage with Water Penetration Monitoring*)

## Purpose of Monitoring System

The expected lifetime of high voltage underground cables is more than 40 years, provided the cables stay dry during this period. In order to guarantee this aim high voltage cables generally are fitted with a metallic sheath, protecting the cable core from liquid and even vaporised water. Although the cables are buried in ground they are not automatically safe for their lifetime. Local pressure on the outer sheath caused by improper bedding material and casual third party damage caused by construction work can harm the metal sheath. Depending on the presence of water in the ground, the water can penetrate undetected into the interior of the cable.
Immediate detection and location of water in the cable screen is performed by a water penetration monitoring system as the necessary precondition for effective repair of the cable.

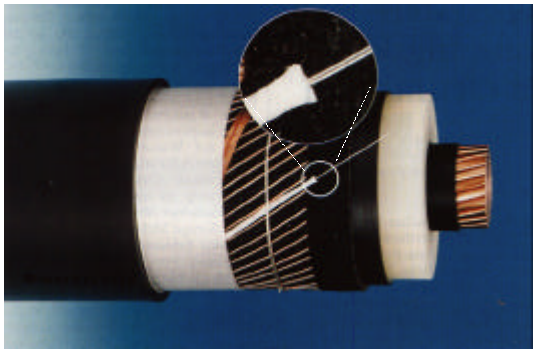

Fig. 1:
XLPE insulated HV cable with integrated water sensors

## Method of Water Penetration Monitoring System

The water penetration monitoring system consists of water sensors integrated in the HV cables, the measuring device, link boxes and interconnecting cables. The water sensors are special insulated wires which insulation resistance changes some decades in case of presence of water. The measuring device continuously measures the DC insulation resistance of the water sensors as an indication of water penetration and performs fault location by means of the voltage across the sensors in case of an effected cable link. DC measurement with filtering off all AC noise guarantees high accuracy of fault location. Measurement results are evaluated automatically in order to recognise any faulty phase and calculate the fault location.

**Cables with electrical Water Sensors**

The water sensor consists of a small special wire and insulation and does not require additional space in cable design. In case of XLPE insulated cables with aluminium laminated polyethylene sheath and copper wire screens electrical water sensors are integrated in the cable screen (Fig.1). Cables with different sheath designs are suitable too for integration of water sensors.

**Measuring Device**

The measuring device (Fig.2) operates automatically and feeds DC currents in adjustable time intervals into the intermediately grounded sensor loops. Up to 5 three-phase cable systems can be monitored simultaneously.

Fig.2: Water penetration measuring device

The system itself can be operated with any electrical power supply. The decrease of insulation level of the water sensors lower than pre-adjusted alarm thresholds will cause an alarm with automatic fault location. Measuring results are calculated internally by the device and shown directly on a display e.g. as a particular cable length from the substation to the fault. Relay contacts are provided for external indication. The measuring device can be integrated in customer- or RTTR (Real Time Thermal Rating) -computer application in order to achieve highest convenience in operational properties.

**Auxiliary Parts of Installation**

At both ends of the cables the sensors are connected to interconnecting cables and passed through the accessories. The cables are clamped in joint boxes with special sheath voltage limiters. These surge limiters are grounding all induced energy actively by the over voltage itself.

With cross-bonded screens of the HV cable water monitoring is as well applicable too. In that case, water sensor link boxes are installed additionally to the screen link boxes next to the respective joints. These boxes enable connections of the water sensors in the same sequence as the cable screens in order to avoid differences of induced voltages between these two electrical components on the cable core (Fig.3).

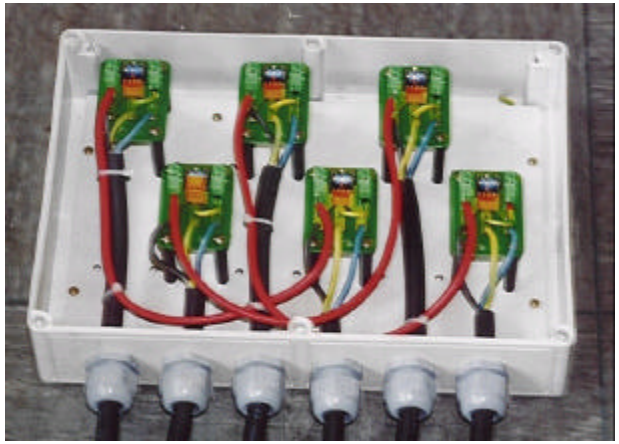

Fig.3: Cross bonding of water sensors

**Installation of a Cable Plant with Water Sensors**

All properties of the cable i.e. longitudinal water tightness, bending radii, laying conditions etc. are not effected adversely by the water sensor, which do not need special installation methods and do not limit pulling length or laying condition. Cables can be laid in ground or ducts and in any formation.

In joints and terminations the sensors are connected to common installation cables with high insulating sheaths. All types of accessories are suitable with only small adaptation in installation.

After installation generally a 5 kV DC test of the cable sheath is performed in order to demonstrate its integrity. This test is also supported by all electrical properties of the monitoring system, e.g. break down voltage of link boxes, provided the sensors are connected to the respective cable sheaths.
Conventional sheath voltage tests of the cable system during lifetime are not necessary any longer, because the system is monitoring the tightness of the sheath by means of insulation resistance.

**Tests**

Tests in laboratory (Fig.4) and in field operation have shown the reliability of the complete water monitoring system when operated on a simulated three-phase HV cable system as well as in commercial high voltage cable applications. There the capability to detect and to locate failures between some minutes and hours after ingress of water into the cable screen with a high accuracy of less than 1% deviation even under AC noise was convincingly demonstrated.

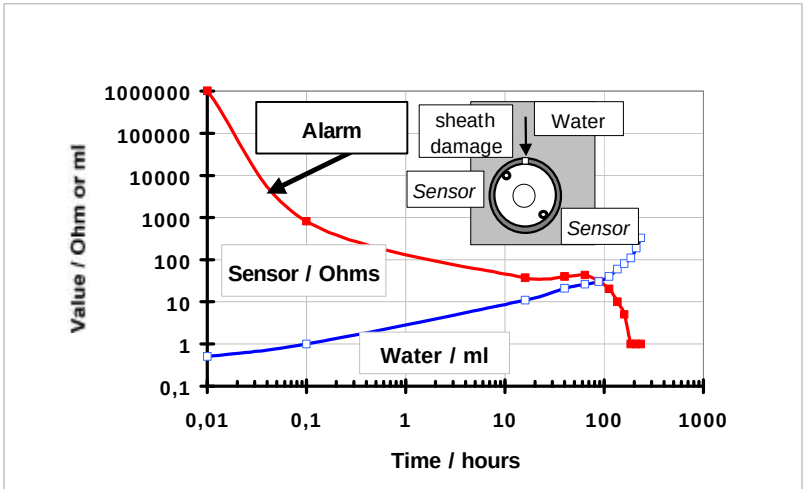


Fig.4: Water penetration and sensor resistance under test conditions similar to IEC 60 840 water penetration test

**Cable Repair**

In case of detected and automatically located water ingress to the cable the fault should be repaired as soon as possible.
The method of drying and repair of cable depends on the damage of sheath and screen.

## Customer Advantages

Water penetration monitoring is advisable in case of important power links to be operated with minimised risks of outage and power interruption due to maintenance, repair or break down.
The advantages of a water monitoring system are obvious if cables are laid close together and where the risk of a third party cable damage is likely.
Also cables laid in ground with high ground water level are a subject to consider about water penetration monitoring.

- Minor additional Investments
- Continuous water detection under operating conditions
- No need of routine HV-tests of cable sheaths
- Locating of failure with high accuracy of <1% deviation
- Immediate water detection – that means less water penetration
- Water monitoring reduces the repair cost and unplanned outage time and increases the safety of the energy supply
- Dry cables – means maximum life time

## References

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IEE POWER ENGINEERING JOURNAL JUNE 2002 Volume 16 No 3, London, UK

*) Supply of high voltage cables with integrated water sensors and monitoring devices by industrial partners